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Declaration

I, Mariko Uchida, a translator of Fukuyama Sangyo Honyaku Center, Ltd., of 16-3, 2-chome, Nogami-cho, Fukuyama, Japan, do solemnly and sincerely declare that I understand well both the Japanese and English languages and that the attached document in English is a full and faithful translation, of the copy of Japanese Unexamined Patent No. Hei-9-79204 laid open on March 25, 1997.



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ACTUATOR

Japanese Unexamined Patent No. Hei-9-79204

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Applicant: Toshiba Corporation

Inventor: Osamu KAWAKAMI

Inventor: Satoshi AOYAGI

Patent Attorney: Takehiko SUZUE

SPECIFICATION

[TITLE OF THE INVENTION] Actuator

[ABSTRACT]

[Object] An object of the present invention is to provide, in a flexible actuator having a movable portion at its tip, a medical actuator wherein an improvement in safety and reliability has been realized by circumventing an inconvenience in external leakage of a pressure fluid sent to pressure chambers provided in the movable portion due to a rupture of a wall surface of the pressure chambers or a leak through a pinhole.

[Solution means] A discharging space 6 is formed by enclosing a flexible actuator 2 attached to the tip of a catheter 1 by a tube 5 having stretchability. If pressure fluid leaks into this space, leakage of the pressure fluid is detected by leading the same to a leak detection device 7 through a discharge tube 8. When a leak is detected, pressurization is stopped to prevent leakage of the pressure fluid into a human body beforehand.

[WHAT IS CLAIMED IS;]

[Claim 1] An actuator the inside of whose tubular elastic body is separated into a plurality of pressure chambers by a partition portion extended in the axial direction and which displaces and actuates said tubular elastic body in an arbitrary direction by variably controlling pressures of these respective pressure chambers by a pressure fluid, wherein

the circumference of said tubular elastic body is covered with a tube having stretchability for hermetic sealing.

[Claim 2] An actuator the inside of whose tubular elastic body is separated into a plurality of pressure chambers by a partition portion extended in the axial direction and which displaces and actuates said tubular elastic body in an arbitrary direction by variably controlling pressures of these respective pressure chambers by a pressure fluid, wherein

a tube having stretchability, for covering the circumference of said tubular elastic body to hermetically seal the tubular elastic body and a leak detection means for detecting leakage of the pressure fluid from said tubular elastic body are provided.

[Claim 3] The actuator as set forth in Claim 2, wherein

a tube provided between the outer circumferential surface of the tubular elastic body and tube, for externally leading out pressure fluid leaked from the tubular elastic body and a detection device connected to this tube, for detecting leakage of the pressure fluid are provided.

[Claim 4] An actuator the inside of whose tubular elastic body is separated into a plurality of pressure chambers by a partition portion extended in the axial direction and which displaces and actuates said tubular elastic body in an arbitrary direction by variably controlling pressures of these respective pressure chambers by a pressure fluid, wherein

a plurality of pressure fluid supply tubes independently provided for said pressure chambers, respectively, at a base end portion of said tubular elastic body and a pressure fluid adjusting means for independently supplying and controlling the pressure fluid for said pressure chambers, respectively, via these supply tubes are provided, and

a fluid filled inside between said supply tubes and said pressure fluid adjusting means is sealed for each system of said supply tubes, respectively.

[Claim 5] The actuator as set forth in Claim 4, wherein

said compression chambers and pressure chambers are formed as tubular elastic bodies formed of an anisotropic elastic material and have a structure to deform in an externally applied stress direction.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Invention] The present invention relates to an actuator having a movable portion at its tip, which is preferably utilized in a shift guiding mechanism portion, a soft-touch driving mechanism portion and the like in a meandering canaliculus, etc., and which utilizes a modulus deformation due to a fluid pressure energy. In addition, the present invention relates to a medical actuator wherein an improvement in safety and reliability has been realized by circumventing an inconvenience in external leakage of a fluid for adjusting an operating pressure.

[0002]

[Prior Arts] Priorly, in order to collect and analyze bile secreted from a duodenum, a thin catheter called a sonde is

inserted orally or through a nostril, passed through the stomach, and lead to a duodenum, however, since the thin catheter has no movability at its tip, a smooth insertion into the canaliculus is extremely difficult even for a skilled medical practitioner, and normally, thirty minutes to one hour is required to complete an insertion.

[0003] When an endoscope is used, since movability of its tip is satisfactory, it can be easily inserted into a duodenum, however, its outward form is approximately 10mm, therefore, the burden on a patient is great in a prolonged examination.

[0004] As a method for solving these problems, provided is a medical actuator having a movable portion called a flexible actuator at its tip, and a small diameter, with excellent operability. In this medical actuator, when operating the movable portion, since fluid is pressurized and sent to a plurality of pressure chambers provided in the movable portion, there contained is a potential hazard such that the fluid of the pressure chambers leaks out into a body due to wear damage to a wall surface of the pressure chambers, a break, a rupture, or a leak through a pinhole.

[0005] In addition, in recent years, actuators to carry out an investigation, inspection or the like of a narrow portion having a large number of gas tubes and curved surfaces and,

moreover, rubber-like actuators, etc., to operate by utilizing a pressure difference in a fluid, such as endoscopes have been variously developed.

[0006] In these actuators, a joystick or valve is utilized to obtain a pressure difference in a fluid. A joystick drives a piston attached to an end portion of a manual lever to pressurize or depressurize a fluid inside a cylinder. A valve can obtain a pressure difference by passing/blocking a fluid compressed by a compressor.

[0007] The joystick and valve are, since a sliding portion exists between the piston and cylinder, provided with various seals so as to prevent a working fluid from leaking outside. However, even if these seals are equipped, it is difficult to completely prevent the working fluid from leakage, and moreover, the life-spans of the seals are relatively short and prolonged use causes wear, therefore, in order to carry out a smooth operation and accurate positioning, a high level of maintenance becomes necessary. In addition, because of a mechanical complexity and the large number of components, problems have also existed in the aspects of manufacturing costs and reliability.

[0008]

[Themes to be Solved by the Invention] As described above, in

the conventional medical actuator, when operating the movable portion, since a fluid is pressurized and sent to a plurality of pressure chambers provided in the movable portion, there contained is a potential hazard such that a fluid of the pressure chambers leaks out into a body due to wear damage to a wall surface of the pressure chambers, a break, a rupture, or a leak through a pinhole.

[0009] In addition, in the conventional rubber-like actuators to operate by utilizing a pressure difference in a fluid, since a joystick and/or valve is used and a sliding portion exists between the piston and cylinder, these are provided with various seals so as to prevent a working fluid from leaking outside. However, even if these seals are equipped, it is difficult to completely prevent the working fluid from leakage, and moreover, the life-spans of the seals are relatively short and a prolonged use causes wear, therefore, in order to carry out a smooth operation and accurate positioning, a high level of maintenance becomes necessary. In addition, because of a mechanical complexity and the large number of components, problems have also existed in the aspects of manufacturing costs and reliability.

[0010] The present invention has been made in view of the above-described circumstances, and an object thereof is to

provide, in a flexible actuator having a movable portion at its tip, the inside of whose tubular elastic body is separated into a plurality of pressure chambers by a partition portion extended in the axial direction and which displaces and actuates a tip portion of the tubular elastic body in an arbitrary direction by variably controlling pressures of these respective pressure chambers by a pressure fluid, a medical actuator wherein an improvement in safety and reliability has been realized by circumventing an inconvenience in external leakage of a pressure fluid sent to the pressure chambers provided in the movable portion due to a rupture of a wall surface of the pressure chambers or a leak through a pinhole.

[0011] In addition, an object of the present invention is to provide an actuator wherein a fluid control mechanism has been simplified by eliminating a joystick, valve or the like from the fluid control mechanism and an improvement in safety and reliability has been realized by securely preventing a working fluid from leakage.

[0012]

[Means for Solving Themes] The present invention provides an actuator the inside of whose tubular elastic body is separated into a plurality of pressure chambers by a partition portion extended in the axial direction and which displaces and

actuates the tubular elastic body in an arbitrary direction by variably controlling pressures of these respective pressure chambers by a pressure fluid, and is characterized in that the circumference of the tubular elastic body is covered with a tube having stretchability for hermetic sealing.

[0013] Moreover, the present invention provides an actuator the inside of whose tubular elastic body is separated into a plurality of pressure chambers by a partition portion extended in the axial direction and which displaces and actuates the tubular elastic body in an arbitrary direction by variably controlling pressures of these respective pressure chambers by a pressure fluid, and is characterized in that a tube having stretchability, for covering the circumference of the tubular elastic body to hermetically seal the tubular elastic body and a leak detection means for detecting leakage of the pressure fluid from the tubular elastic body are provided.

[0014] Namely, an actuator of the present invention is characterized in that a movable portion at its tip is composed of a tubular elastic acting body separated into a plurality of pressure chambers by a partition, and in a manner surrounding the whole circumferential surface of this tubular elastic acting body en bloc, the tubular elastic acting body is covered with a tube having stretchability so that the risk of external

leakage of a pressure fluid leaked from the tubular elastic acting body can be eliminated and a discharging space for a leaked pressure fluid can be formed in the tube. In addition, the present invention is characterized in having a device for detecting a leaked-out fluid.

[0015] Moreover, the present invention provides an actuator the inside of whose tubular elastic body is separated into a plurality of pressure chambers by a partition portion extended in the axial direction and which displaces and actuates the tubular elastic body in an arbitrary direction by variably controlling pressures of these respective pressure chambers by a pressure fluid, wherein a plurality of pressure fluid supply tubes independently provided for the pressure chambers, respectively, at a base end portion of the tubular elastic body and a pressure fluid adjusting means for independently supplying and controlling the pressure fluid for the pressure chambers, respectively, via these supply tubes are provided, and a fluid filled inside between the supply tubes and the pressure fluid adjusting means is sealed for each system of the supply tubes, respectively.

[0016] Namely, in an actuator, formed of a tubular elastic body whose inside is separated into a plurality of pressure chambers by a partition extended in the axial direction, having an

elastic acting body which operates by adjusting respective pressures of the pressure chambers, the present invention is characterized in that the pressure chambers in the elastic acting body, supply tubes to lead a pressurized fluid to the pressure chambers, and compression chambers to pressurize a fluid are provided with a sealing structure to isolate the fluid from the outside. In addition, the present invention is characterized in that, similar to the pressure chambers in the elastic acting body, the compression chambers are formed as a tubular elastic body of an anisotropic elastic material and have a structure to deform in an externally applied stress direction.

[0017]

[Preferred Embodiment] Hereinafter, embodiments of the present invention will be described in detail with reference to the following drawings. First, a first embodiment of the present invention will be described. In the first embodiment of the present invention, a flexible actuator having a movable portion at its tip is constructed in a manner having inside a plurality of pressure chambers adjacent and united to each other. Since these pressure chambers have flexibility in the longitudinal direction and are structured to hardly stretch in the diametrical direction, these are stretched in only the

longitudinal direction by application of pressure through a pressuring tube connected thereto. Herein, when different pressures are applied to the pressure chambers united in a transverse direction, although a pressure chamber to which a higher pressure has been applied intends to stretch, a pressure chamber in a lower pressure condition is not deformed. Consequently, the flexible actuator is bent toward a pressure chamber which does not stretch similarly to a bimorph. In the flexible actuator of a fixed length, a bending angle is determined based on a pressure difference between the pressure chambers.

[0018] In the embodiment of the present invention, the outside of the above-described flexible actuator is sealed by a tube having stretchability in a manner enclosing the whole. In addition, to a discharging space formed between this tube and outer circumferential portion of the flexible actuator, a discharge tube to lead out a fluid leaked out of the pressure chamber(s) is connected. Furthermore, via the discharge tube, a detection device to detect a fluid leak is provided. When a fluid leak is detected by this leak detection device, pressurization of the fluid is stopped and an alarm is raised to inform an operator so that an appropriate measure can be swiftly carried out, such that, for example, for medical use,

extracting a catheter provided with this actuator from a body.

[0019] Moreover, operations of a flexible actuator as a tubular elastic acting body have been described in detail in Japanese Patent Application No. Hei-1-247809. Fig. 1 is an exploded perspective view showing a construction of the first embodiment of the present invention. Herein, a medical actuator is cited as an example.

[0020] To a tip of a thin catheter 1 (a diameter of 3mm, for example), a flexible actuator 2 is attached, and this is used as a guide during an insertion into a body. In this embodiment, shown is a case where the flexible actuator is constructed in a manner having three pressure chambers 10a, 10b, and 10c.

[0021] To these three respective pressure chamber 10a, 10b, and 10c, pressurizing tubes 3a, 3b, and 3c to lead a pressurizing fluid are connected, respectively, and as described above, by adjusting pressures applied to the three pressurizing tubes by a pressure device 4, the tip of the flexible actuator 2 can be curved to an arbitrary direction.

[0022] The flexible actuator 2 according to this embodiment encloses the whole of the above-described three respective pressure chambers 10a, 10b, and 10c by a tube 5 having stretchability.

[0023] Then, to a discharging space 6 formed between the outer

circumferential surface of the above-described three respective pressure chambers 10a, 10b, and 10c and tube 5, a discharge tube 8 is connected, and this leads a fluid leaked from all or a part of the pressure chambers 10a, 10b, and 10c to a leak detection device 7.

[0024] An A-A' section of Fig. 1 at this time is shown in Fig. 2. Herein, the discharging space 6 is illustrated as a space having a section area between the tube 5 and outer wall of the flexible actuator 2, however, in actuality, the tube 5 and the outer wall of the flexible actuator 2 are approximately closely fitted, and normally, a space does not exist. If the outer wall of the flexible actuator 2 ruptures or produces a pinhole or the like for some reason or another and leakage of a pressure fluid occurs, the inside pressure fluid leaks out while spreading out by pressing the discharging space 6. In contrast thereto, by a contractive force of the tube 5, the leaked pressure fluid is lead to the discharge tube 8 and is discharged from the discharging space 6. Therefore, even if a fluid leaks from all or a part of the pressure chambers 10a, 10b, and 10c, this pressure fluid does not leak out into a body and safety is secured.

[0025] A constructional example of the above-described leak detection device 7 is shown in Fig. 3. In the leak detection

device 7, pressure is monitored by a pressure monitoring device 21 at all times. When a pressure fluid leaks out and pressure of the discharge tube 8 rises and becomes a set pressure or more, a pressurization stop signal is outputted from a control portion 22 to the pressure device 4 to limit the pressure fluid leakage to a minimum so as to prevent the tube 5 from breaking. Furthermore, by raising an alarm such as an alarm sound, an alarm lamp, etc., the catheter 1 provided at the tip of the flexible actuator 2 is swiftly extracted by an operator from a body, whereby time for which the defective actuator is placed inside the human body is shortened, and safety is secured.

[0026] Not only by a method as a result of pressure monitoring, the leak detection device 7 can similarly detect a leak by monitoring a flow rate. Or, by providing, in the respective pressure chambers 10a, 10b, and 10c, for example, an extra-fine balloon as a pressure sensor and comparing a presumed pressure determined from a flow rate of the pressure fluid with a detected pressure by the pressure sensor, a leak can also be detected.

[0027] A modification of the second embodiment is shown in Fig. 4. Herein, a sectional view by a section similar to Fig. 2 is shown. In a constructional example shown in this Fig. 4, as well, similar to the embodiment as shown in Fig. 2, a flexible

actuator is constructed with three pressure chambers 10a, 10b, and 10c. Herein, elastic acting bodies to form these three pressure chambers 10a, 10b, and 10c are respectively independently constructed. Other aspects of the construction are identical to those of the embodiment shown in Fig. 1 and Fig. 2.

[0028] In the construction as shown in Fig. 4, a gap 31 between mutual lateral walls of the pressure chambers is illustrated as a space, however, since the respective pressure chamber walls are approximately closely fitted, a space does not normally exist, but the walls are mutually united at important positions (at fixed intervals in the longitudinal direction, for example).

[0029] Herein, at a part where the pressure chambers 10a and 10b are in contact, if a rupture or a pinhole occurs in the wall of 10a, pressure fluid leaks out through the gap 31 between the pressure chambers into the discharging space 6 formed by the tube 5. Thereafter, leakage is detected in a manner similar to the above-described embodiment as shown in Fig. 1 and Fig. 2. By this embodiment, leakage of a pressure fluid from one pressure chamber to another pressure chamber, which may occur in a case where, for example, a three-chamber flexible actuator has been integrally molded, can also be detected

beforehand.

[0030] By employing a flexible actuator of such a construction as described above, a medical actuator to be inserted in a human body can be provided with higher safety. Next, a second embodiment of the present invention will be described.

[0031] The second embodiment of the present invention is, in a flexible actuator which is formed of a tubular elastic body whose inside is separated into a plurality of pressure chambers by a partition extended in the axial direction and which comprises: elastic acting bodies which operate by adjusting respective pressures of the pressure chambers; supply tubes connected to end portions of the respective tubular elastic bodies and supply a fluid to apply pressure to the respective tubular elastic bodies; and a means for pressurizing adjustment of respective pressures of the pressure chambers so as to operate the respective tubular elastic bodies with a multiple degree of freedom, characterized in that a fluid filled inside between the supply tubes and the means for pressurizing adjustment is sealed for each system of the supply tubes, respectively. Moreover, the tubular elastic body whose inside is separated into a plurality of pressure chambers by a partition extended in the axial direction is herein referred to as an FMA (Flexible Micro Actuator).

[0032] Fig. 5 is a perspective view showing a construction of an actuator according to the second embodiment of the present invention. Herein, a construction wherein a pressure chamber installed inside an FMA 51 is provided as a pair is exemplified, however, for example, as shown in Fig. 2, the pressure chambers may be composed of three or a plurality of chambers more than the same.

[0033] In the FMA 51 of an actuator, to a base end portion 53, one-side ends of supply tubes 54a and 54b to supply a fluid are fitted by insertion and fixed. The other-side ends of the supply tubes 54a and 54b are fitted by insertion and fixed to a pressurizer 55, which is a means for pressurizing adjustment of the above fluid.

[0034] A pressure chamber 52a provided inside the FMA 51 is connected to the supply tube 54a. Also, a pressure chamber 52b installed inside the FMA 51 is connected to the supply tube 54b.

[0035] A partition 57 is provided between the pressure chambers 52a and 52b installed inside the FMA 51. This partition 57 has, in the up-and-down direction of the drawing, a flexible structure for which the same easily curves and has, in the horizontal direction of the drawing, a rigid structure for which the same hardly curves.

[0036] In addition, a partition 59 is also provided between compression chambers 56a and 56b installed inside the pressurizer 55. This partition 59 has, in the up-and-down direction of the drawing, a flexible structure for which the same easily curves and has, in the horizontal direction of the drawing, a rigid structure for which the same hardly curves.

[0037] The supply tubes 54a and 54b use a material which produces a much smaller stretching amount as a result of the pressure of a fluid filled inside than a stretching amount of the FMA 51. In Fig. 9, for ease of explanation of an operation, the supply tubes 54a and 54b are provided with a point 58 where the same are intersected at 180° midway.

[0038] In Fig. 6, when the pressurizer 55 is curved upward A as illustrated by an external stress, for example, by hand, the pressure chamber 56a is compressed and its internal volume is contracted, and a fluid charged in the pressure chamber 56a is pressurized to pressurize the pressure chamber 52a via the supply tube 54a, whereby the FMA 51 is curved in an illustrated upward direction A' as shown in Fig. 7.

[0039] On the other hand, the pressure changer 56b is elongated, and to a fluid filled inside, a negative pressure is applied compared to its initial state to reduce the pressure in the pressure chamber 52b via the supply tube 54b. Thereby, the

FMA 51 acts so as to curve in an illustrated upward direction A' as shown in Fig. 7.

[0040] Herein, the used fluid, when a material producing a small change in volume due to an externally applied stress is used, curves the pressurizer 55, and a changed volume in the compression chambers 56a and 56b is equal to an amount of change in the pressure chambers 52a and 52b, therefore, by appropriately setting sectional areas and lengths of the compression chambers 56a and 56b and pressure chambers 52a and 52b, the amount of change in the pressurizer 55 and FMA 51 can be adjusted.

[0041] Next, referring to Fig. 8, another embodiment of a means to pressurize a fluid filled in a compression chamber will be described. Similar to the above-described embodiments, to a base end portion 53 of an FMA 51, end portions of supply tubes 54a and 54b are fitted by insertion and fixedly fitted. The other ends of the supply tubes 54b and 54a are fitted by insertion and fixedly fitted to compression chambers 60a and 60b.

[0042] In Fig. 9, a detailed view of the compression chamber 60a is shown, and an A-A auxiliary view of Fig. 9 is shown in Fig. 10. A side wall 61 of the compression chamber 60a and a partition 63 to which the supply tube 54 is fixedly fitted

by insertion have such a strength as not to be stretched or deformed against a pressure change in a fluid filled inside. On the other hand, a partition 62a of the compression chamber 60a is of a flexible material or structure having a sufficient strength, response, and resilience without breaking against an external stress C.

[0043] A construction as shown in Fig. 8 is such that, by actuating a solenoid 65, a plunger 64 is shifted in a direction C by an electromagnetic force thereof so as to provide the partition 62 with a predetermined pressing force. A power supply 67 to actuate the solenoid 65 is supplied to the solenoid 65 via a switch 66.

[0044] The solenoid 65 produces an electromagnetic force upon turning on of the switch 66 and shifts the plunger 64 in the direction C, and returns to its original home position as a result of an effect of a coil spring (unillustrated) upon turning off of the switch 66. Accordingly, a fluid filled in the compression chamber 60a is selectively pressurized by turning on and off the switch 66.

[0045] Herein, by turning on and off the switch 66, pressurization values are provided as two values, however, it is also possible to use a driving means which can continuously change the pressing force in place of the solenoid and plunger.

For example, a magnet may be used in the above plunger so that a continuous current is supplied to the solenoid. In addition, as a method to be manually carried out, as shown in Fig. 11, it is possible to move a joystick lever 68 and press the partitions 62a and 62b of the compression chambers 60a and 60b by pressing surfaces 70a and 70b via a fulcrum 69.

[0046] By employing such a construction wherein a pressure fluid is hermetically filled into each pressure chamber of a tubular elastic body, a flexible microactuator can be driven without having a movable portion of a mechanism through which a fluid can leak outside, a seal and the like, and accordingly, a great improvement in reliability can be realized. In addition, the construction can be simplified, stable operations with fewer malfunctions can be maintained for a prolonged period of time, and a low-priced and compact construction can be realized.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] An exploded perspective view showing a construction of an actuator according to a first embodiment of the present invention.

[Fig. 2] A sectional view along a line A-A' of Fig. 1.

[Fig. 3] A block diagram showing a construction of a leak detection device in the above-described first embodiment.

[Fig. 4] A sectional view showing, in contrast to Fig. 2, a modification of the first embodiment of the present invention.

[Fig. 5] A perspective view showing a construction of an actuator according to a second embodiment of the present invention.

[Fig. 6] An operation explanatory view of a pressurizer of the above-described second embodiment.

[Fig. 7] An operation explanatory view of an FMA of the above-described second embodiment.

[Fig. 8] A perspective view showing a construction by a first modification according to the above-described second embodiment.

[Fig. 9] An operation explanatory view of the pressurizer of Fig. 8.

[Fig. 10] A sectional view along a line A-A of Fig. 9.

[Fig. 11] A perspective view showing a construction by a first modification of said second embodiment

[Description of Symbols]

- 1 ... Catheter
- 2 ... Flexible actuator
- 5 ... Tube
- 6 ... Discharging space

- 7 ... Leak detection device
- 8 ... Discharge tube
- 21 ... Pressure monitoring device
- 22 ... Control portion
- 51 ... FMA (tubular elastic body; flexible micro actuator)
- 52 (52a, 52b) ... Pressure chamber installed inside an FMA
- 53 ... Base end portion of an FMA
- 54 (54a, 54b) ... Supply tube
- 55 ... Pressurizer
- 56 (56a, 56b) ... Compression chamber installed inside a
pressurizer
- 57 ... Partition between two pressure chambers installed
inside an FMA
- 58 ... Point where supply tubes are intersected
- 59 ... Partition between two compression chambers installed
inside a pressurizer
- 60 (60a, 60b) ... Compression chamber
- 61 ... Side wall of a compression chamber
- 62 ... Partition of a compression chamber
- 63 ... Partition of a compression chamber to which a supply
tube is fixedly fitted by insertion
- 64 ... Plunger
- 65 ... Solenoid

66 ... Switch

67 ... Power source

68 ... Joystick lever

69 ... Joystick lever fulcrum

70 ... Joystick pressing surface

Fig.1

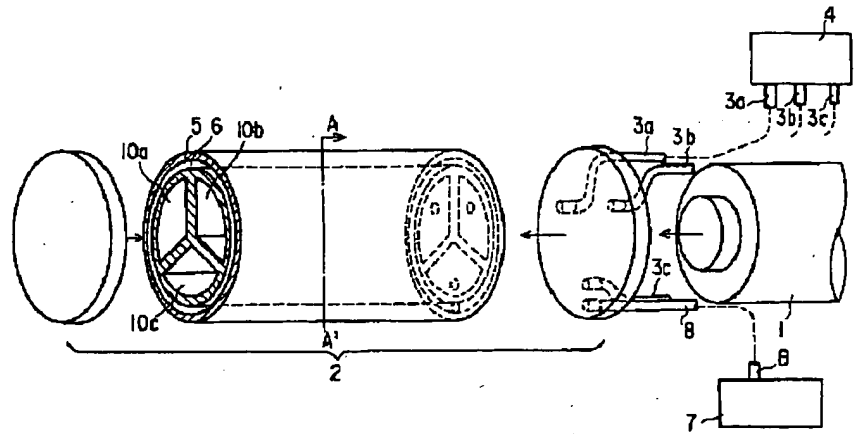


Fig.2

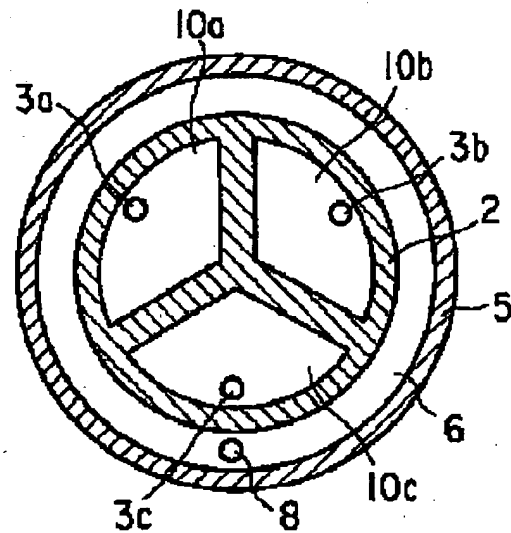


Fig.3

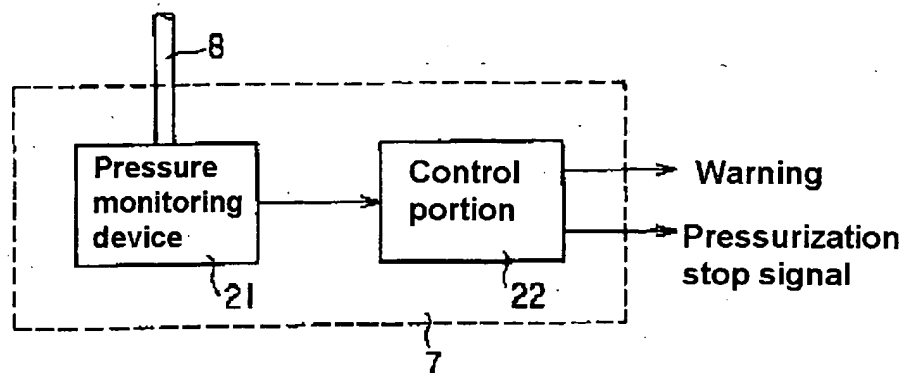


Fig.4

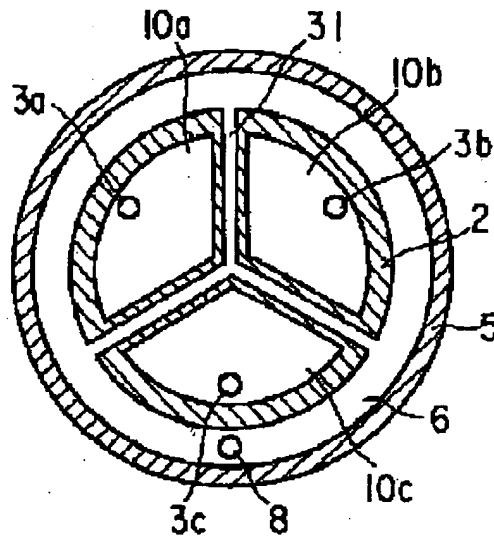


Fig.5

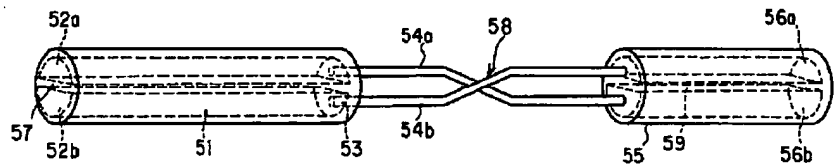


Fig.6

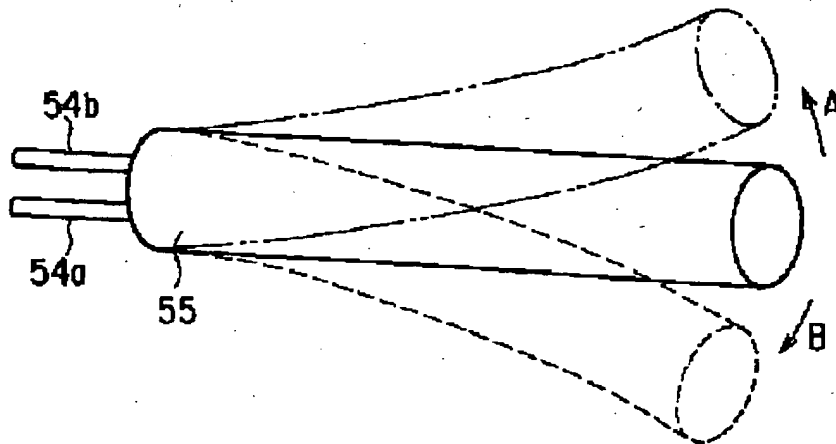


Fig.7

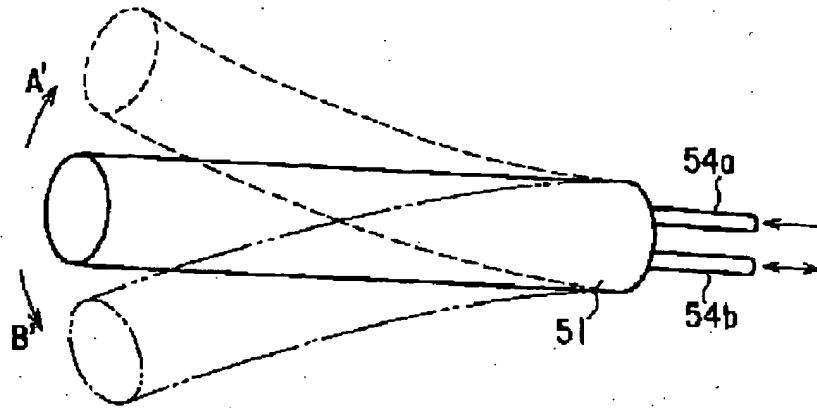


Fig.8

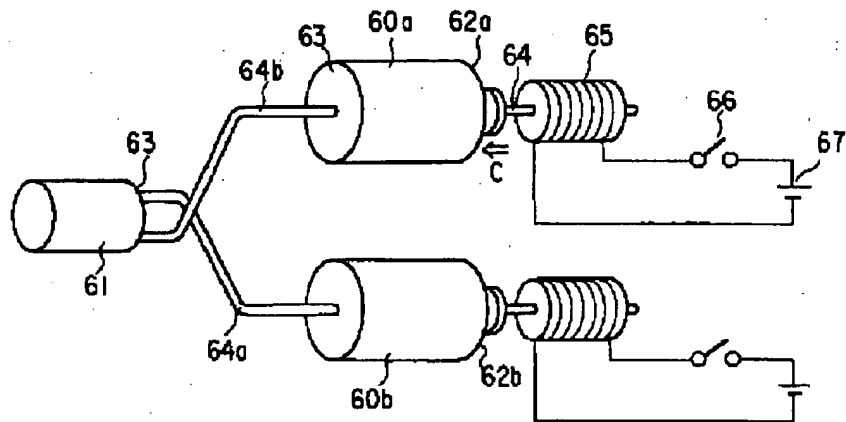


Fig.9

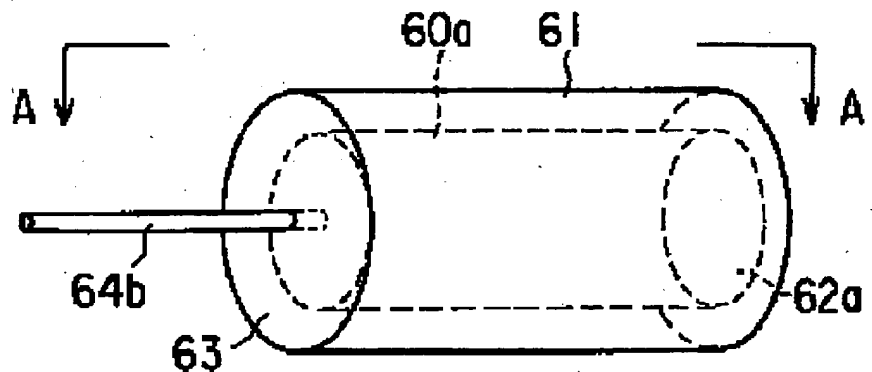


Fig.10

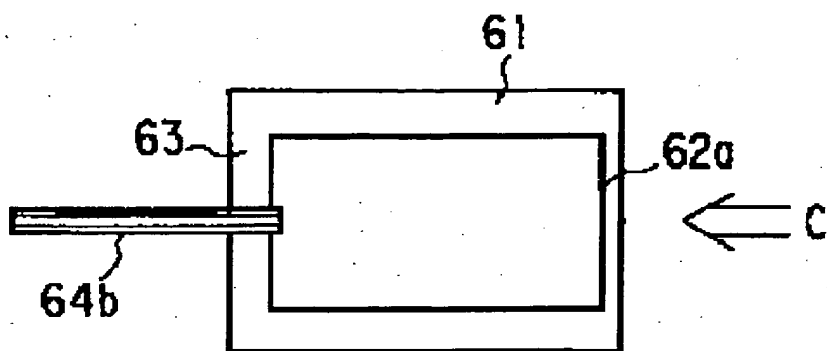
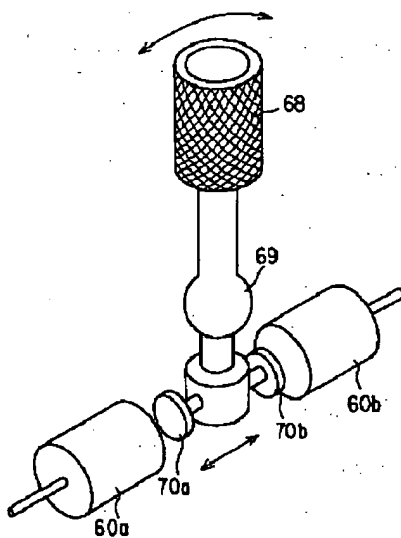


Fig.11



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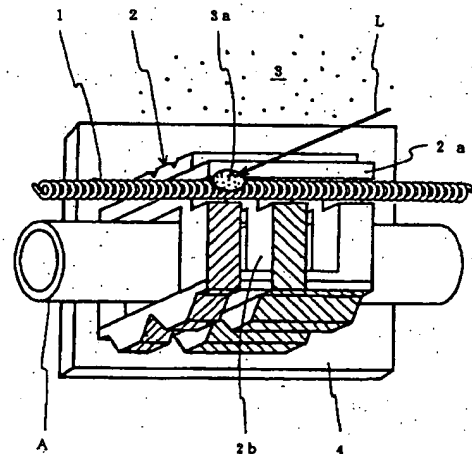
(54) 【発明の名称】 接合方法

(57) 【要約】

【課題】 mmオーダー以下のマイクロ部品であっても、3次元的に自在に接合することが可能な新たな接合方法を提供すること。

【解決手段】 互いに接合すべき部品、例えば、カテーテルに付与される能動屈曲機構の形状記憶部材 1 と接続ユニット 2 の、接合を意図する部位に CVD 法を用いて有機金属化合物の蒸気から金属を堆積させることによって、その部位を前記金属にて接合することを特徴とする、マイクロアセンブリに特に有用な接合方法である。少なくとも接合を意図する部位を、ペルチェ素子 4 等を用いて冷却することが好ましい。また CVD 法のうち、連続紫外線レーザー光を用いる光 CVD 法が好ましい。

【効果】 接合剤が金属であるので、本発明により耐熱性の接合構造が得られる。



1 形状記憶部材

2 接続ユニット

3 有機金属化合物の蒸気

3 a 堆積した金属

4 ペルチェ素子

【特許請求の範囲】

【請求項1】 互いに接合すべき部品の接合個所にCVD法を用いて有機金属化合物の蒸気から金属を堆積させることを特徴とする接合方法。

【請求項2】 有機金属化合物が $M\text{O}(\text{CO})_x$ である請求項1記載の接合方法。

【請求項3】 CVD法が光CVD法である請求項1または2記載の接合方法。

【請求項4】 CVD法が熱CVD法である請求項1または2記載の接合方法。

【請求項5】 少なくとも接合個所を冷却した状態においてCVD法を適用する請求項1～4のいずれかに記載の接合方法。

【請求項6】 冷却がベルチェ素子によってなされるものである請求項5記載の接合方法。

【請求項7】 光CVD法が、連続紫外線レーザー光を用いたものである請求項1、2、3、5または6のいずれかに記載の接合方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は接合方法に関するものであって、詳しくは、マイクロマシンに用いられる部品間の微細な接合などに有用な接合方法に関する。

【0002】

【従来の技術】マイクロマシン（または、マイクロメカニズム）は、 μm オーダーから数 mm オーダー程度の超小型乃至小型の機械、機械要素、ロボットなどであって、特に細胞操作や医療等の分野において今後における多用が期待されている。近年、マイクロセンサやアクチュエータなど、マイクロマシンに利用可能なマイクロ部品が数多く提案されている。これら多くの微小なマイクロ部品からマイクロマシンを組立てるには、マイクロアセンブリ技術が必要不可欠である。そのなかでも接合技術は組立てのために特に重要であって、その接合の対象は微小なマイクロ部品同士である場合が多く、接合個所の大きさが例えば面積にして数 μm ～数十 μm 平方程度の微小な場合もある。しかも、密着した平面同士を接合するような単純な場合だけではなく、互いに交差する二本の極細線同士を一点で接合する場合や、微細で複雑な形状記憶部材をハウジングの微小な凹部に嵌め込んだ後接合するなど、三次元的な接合も要求される。

【0003】密着した平面同士を接合するような単純な二次元的接合技術としては、例えば陽極接合が知られている。しかし、全長が mm オーダー以下、特に数 μm オーダーもの微小な機械要素を二次元的に、特に三次元的に接合するには未だ多くの問題がある。例えば、 He-Cd レーザーを用いて紫外線硬化樹脂を局所的に硬化させる技術が、カテーテルの組立の際にマイクロ部品の接合に適用された例がある。しかしこの方法では、未硬化の樹脂部分を溶剤で溶解除去する必要があり、その際にマ

イクロ部品が破損する恐れがある。一方、集束イオンビームを利用したデバイスの移植技術は、マイクロ部品の接合技術としての応用が考えられている。この技術は、集束イオンビームによってスパッタリングを行って、マイクロ部品同士の接合所望個所に原子を堆積させて接合する方法である。しかしこの方法は、接合に長時間を要するので未だ実用上に問題がある。

【0004】

【発明が解決しようとする課題】本発明の課題は、上記問題を解決し、 mm オーダー以下のマイクロ部品であっても、点接合から三次元的接合まで、接合所望個所の状況に応じて自在に接合することが可能な新たな接合方法を提供することである。

【0005】

【課題を解決するための手段】本発明の接合方法は、互いに接合すべき部品の接合個所にCVD法を用いて有機金属化合物のガスから金属を堆積させる、以下に示す特徴を有する。

【0006】1. 互いに接合すべき部品の接合個所にCVD法を用いて有機金属化合物の蒸気から金属を堆積させることを特徴とする接合方法。

2. 有機金属化合物が $M\text{O}(\text{CO})_x$ である上記1記載の接合方法。

3. CVD法が光CVD法である上記1または2記載の接合方法。

4. CVD法が熱CVD法である上記1または2記載の接合方法。

5. 少なくとも接合個所を冷却した状態においてCVD法を適用する上記1～4のいずれかに記載の接合方法。

6. 冷却がベルチェ素子によってなされるものである上記5記載の接合方法。

7. 光CVD法が、連続紫外線レーザー光を用いたものである上記1、2、3、5または6記載の接合方法。

【0007】

【作用】本発明の重要な特徴は、従来では単に薄膜形成法として用いられていたCVD法が、接合方法として、特にマイクロアセンブリにおいては有用な接合方法として利用できることを新たに示したことである。本発明においては、部品の接合所望個所にCVD法を用いて有機金属化合物の蒸気から金属を堆積させる。かくすることにより、接合個所が極く微小な局所であっても、あるいは形状的には線状、面状、更には立体状であっても、自在に接合することが可能となる。また、接合剤が有機物でなく金属であるので、熱的に安定な接合構造が得られる。本発明において、有機金属化合物の蒸気からの金属の堆積は、熱や光などのエネルギーの接合所望個所への局所的な施与によってなし得るが、かかるエネルギー源としてレーザー光、特に連続紫外線レーザー光を用いることによって金属を高速で堆積させることが可能となる。これは、紫外光が原料ガスである有機金属化合物蒸気に吸

収され易く、またパルス光よりも連続光の方が効率よくエネルギーの供給が可能であることによる。また、CVD法による金属の堆積工程において、接合所望個所を適度に冷却することによって後記する理由から金属の堆積速度を早めることができる。

【0008】

【発明の実施の態様】本発明においては、各種の無機材料や有機材料、例えばシリコン、金属、セラミックス、ガラス、プラスチック、など各種の材料の1種あるいは2種以上からなる同種部品の間、あるいは異種材料の部品の間の接合が可能である。具体例を示すと、石英ガラスなどのガラス系光ファイバの先端への各種の部品、例えば石英ガラス製マイクロレンズ、シリコン製や金属製のマイクロセンサ、バルーンや首振り機構用の取り付け金具、金属製形状記憶素子などの接合、各種のマイクロマシン、例えばアクチュエータ、ロボット、マイクロセンサ、などの組み立て上に必要な種々の接合、あるいはプラナプロセスから得られる各種セラミックス製マイクロ部品間の接合、などである。

【0009】本発明における接合は、接合を要する部品の少なくとも接合所望個所の周囲を有機金属化合物の蒸気で満たし、ついで該接合所望個所に集中的に反応エネルギーを供与して該個所に金属を堆積させる。かくすると、堆積した金属により接合が達成される。

【0010】かかる反応エネルギーとしては、CVD法において慣用のもの、例えば熱や光などが用いられるが、光、特にレーザ光が好ましい。光エネルギーの場合には、低温で接合が可能であるので接合個所並びにその近傍の部材を熱で損傷する心配がなく、接合に必要な充分量の光エネルギーを施与することができる。光のうちでもレーザ光は、パワー密度が高くそのビーム径を μm オーダーに絞ることができるので、微細な接合に一層有用である。更にレーザ光のうち、紫外線レーザ光、就中、連続紫外線レーザ光が好ましい。その理由は、紫外光が一般的に原料ガスである有機金属化合物蒸気に吸収され易く、またパルス光よりも連続光の方がより効率よく必要なエネルギー量を供給し得るからである。連続紫外線レーザ光を出力し得るレーザ装置としては、イントラキャビティ非線形光学を用いた第二高調波の Ar^+ レーザ装置や、第四高調波のYAGレーザ装置などが挙げられる。

【0011】反応エネルギーを施与する過程にあつては、少なくとも接合を要する個所のみが有機金属化合物の蒸気で満たされておればよい。しかし実際問題として、該接合個所を含む周囲近傍の全体を該蒸気で満たすことのほうが作業が容易な場合が多い。例えば、予め用意された有機金属化合物の蒸気室内に被接合部品を導入して該室内で接合作業を行う場合である。かかる蒸気室は、例えば真空引きされた室内、例えばCVD法を実施するための密閉槽内、に有機金属化合物を蒸気、液体、

または固体の状態で供給し、該室内を有機金属化合物の蒸気で充填させることにより得られる。この場合、該室内の温度は過度の低温や高温でない限り任意であつてよい。しかし、作業性の観点から、室温あるいはその近傍温度が好ましい。該室内における有機金属化合物の蒸気圧も特に制限はないが、例えば0.1~1000mTorr、特に1~100mTorrが好ましい。

【0012】上記した蒸気室内におけるように、接合所望個所を含む周囲近傍を有機金属化合物の蒸気で満たす接合作業の場合、接合所望個所を低温で、例えば5~10℃、特に0~5℃程度の低温度としておくと、金属を効率よく堆積させることができる。その理由は、接合所望個所の表面における有機金属化合物の濃度が、該表面上での該蒸気の部分的な凝縮や吸着などにより周囲より高くなっているためと思われる。接合所望個所の冷却方法は、任意の方法であつてよく、例えばCVD法を実施するための密閉槽内全体を低温に維持する方法や、接合所望個所だけを局部的に低温に維持する方法等が挙げられる。特に、ペルチェ素子を接合所望個所またはその近傍に配置し、該個所だけを局部的に冷却する方法は、温度調節が簡単であるので好ましい。

【0013】原料の有機金属化合物としては、CVD法にて金属を堆積するものであれば特に制限はない。就中、人体に対して無害で且つ大気中で安定な金属、例えば周期律表の第1B属元素、非放射性的希土類元素、第3B属元素、第4A~第7A属元素、錫、鉛、ビスマス、第8属元素、などの金属の有機金属化合物が好ましい。例えば $\text{Mo}(\text{CO})_6$ 、 $\text{Cr}(\text{CO})_6$ などのヘキサカルボニル化合物、 $\text{Pt}(\text{HFA})_2$ 、 $\text{Pt}(\text{AcAc})_2$ 、 $\text{Au}(\text{CH}_3)_2$ 、 $(\text{C}_5\text{H}_7\text{O})$ などである。これらのうち $\text{Mo}(\text{CO})_6$ は、条件を選べば3 μm /分以上もの高速でMoの堆積が可能である。

【0014】

【実施例】以下、実施例を挙げて本発明をさらに詳細に説明する。

実施例1

図1は、本発明の接合方法を適用してカテーテルに能動屈曲機構を付与するときの組立て工程の一部を示す斜視図である。カテーテルの能動屈曲機構は、カテーテルの外周に該カテーテルの長手方向に沿って複数本の形状記憶部材を適当な間隔を置いて平行に配置した構成を有する。かかる構成によって形状記憶部材の伸縮が筋肉の動作のように作用し、カテーテルを自在に屈曲させることができる。同図において、Aは医療用のカテーテル、1は加熱によって長手方向に収縮するコイル状の形状記憶部材、2は、前記形状記憶部材をカテーテルに沿って配置するために、カテーテルの長手方向に所定の間隔をおいて固定される接続ユニットである。該接続ユニットは全長3mmの微小な部品であり、シリコン層2a、ガラス層2b等のようにシリコン層とガラス層とが陽極接合

によって積層され、その表面にはハッチングで示すような導電回路の層が形成されたマイクロ部品である。カテーテルは、断面が円形で外径が $\phi 1\text{mm}$ のフレキシブルな管状物である。また、3は、有機金属化合物の蒸気であり、3aは、該蒸気から堆積した金属である。本実施例において、上記の装置のうちの形状記憶部材1と接続ユニット2とを矢印Lで示す部位において接合すべく、 15°C において該装置の全体を蒸気圧約 30mTorr の $\text{Mo}(\text{CO})_6$ で満たした真空容器中に設置し、かつ接続ユニット2にベルチエ素子4を当てがってその部分を種々の温度に冷却した。次いで、この状態において接合個所の温度や、レーザー光のレーザーパワーによる Mo の接堆積速度の変化を調べた。この結果、接合個所の温度が -5°C で、波長が 238nm 、レーザーパワーが 7mW の連続紫外線レーザーを用いた時、約 $3\mu\text{m}/\text{min}$ の最大堆積速度が得られた。その条件にて20分間連続紫外線レーザーを照射した後において、接合された形状記憶部材と接続ユニットとの接合の強度を調べたところ、軸方向に約 200mN の荷重を加えても接合部分が外れることはなかった。

【0015】実施例2

本実施例では、カテーテルに他の能動屈曲機構を付与するときの組立てにおいて、本発明を応用する場合の例を示す。図2は、その組立物の斜視図である。同図に示す能動屈曲機構は、カテーテルの先端部を自在に屈曲させるために、カテーテルの周囲に3本の首振り用ワイヤが設けられ、この3本の首振り用ワイヤを操作側から直接引っ張るのではなく、各該ワイヤ間に介在させた形状記憶部材を操作側から収縮させることによってワイヤが引っ張られる構造としたものである。同図に矢印で示す箇所が接合個所である。上記実施例1では面と線との微小部分での立体的な接合であるのに対して、本実施例においてはこの首振り用ワイヤと形状記憶部材とを各端部同士で接合した例である。即ち本実施例は、微細な線と線とを端部で連結する接合である。接合個所は、 Ti-Ni 系合金からなる累線径 $\phi 30\mu\text{m}$ 、コイル外径 $\phi 100\mu\text{m}$ の形状記憶部材の先端面と SUS304 からなる外径 $\phi 30\mu\text{m}$ の首振り用ワイヤの先端面とである。本実施例において、上記装置の全体を 15°C において実施例1で使用した真空容器中に設置し、該容器内を蒸気圧約 30mTorr の $\text{Mo}(\text{CO})_6$ で満たし、かつ

ベルチエ素子を当てがってその部分を -5°C に冷却した。次いで、この状態において波長が 238nm 、レーザーパワーが 7mW の連続紫外線レーザーを20分間照射した後における接合強度を調べたところ、軸方向に約 200mN の荷重を加えても接合部分が外れることはなかった。

【0016】本発明の接合方法は、一般的な接合方法として利用することができるが、互いに接合すべき部品がマイクロマシンを構成する微小部品であるような場合に、その有用性が最も顕著に示される。また本発明の接合方法では、金属により接合されるので、接合個所は耐熱性に優れている。

【0017】

【発明の効果】以上のように本発明の接合方法は、薄膜形成技術であるCVD法を接合に応用するものであり、特にレーザーCVD法の微細で精密な描画能力を、微小な部品同士の精密な接合に生かすことができる。またドライプロセスであるから、接合工程において溶剤などによる部品の損傷がない。また、連続紫外線レーザー光を用いることによって、接合を高速に行なうことが可能となる。さらには、接合する部分を冷却することによって、より高速で金属の堆積を、しかしてより高速で接合を行なうことができる。従って、 mm オーダー以下のマイクロ部品であっても、また接合個所が極く微小な局所であっても、あるいは形状的には線状、面状、更には立体状であっても、自在に接合することが可能となる。さらに接合剤が有機物でなく金属であるので、熱的に安定な接合構造が得られる。

【図面の簡単な説明】

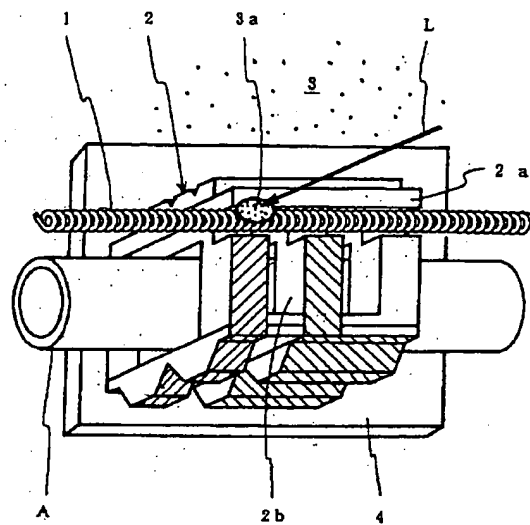
【図1】本発明の接合方法を適用してカテーテルに能動屈曲機構を付与するときの組立て工程の一部を示す斜視図である。

【図2】本発明の接合方法を適用するカテーテルに能動屈曲機構を付与するときの他の組立物の斜視図である。

【符号の説明】

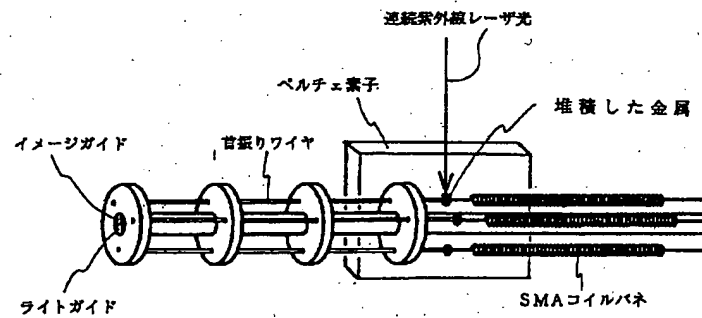
- 1 形状記憶部材
- 2 接続ユニット
- 3 有機金属化合物の蒸気
- 3a 堆積した金属
- 4 ベルチエ素子

【図1】



- 1 形状記憶部材
- 2 接続ユニット
- 3 有機金属化合物の蒸気
- 3 a 堆積した金属
- 4 ペルチェ素子

【図2】



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